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EFFECT OF COMPOSITION OF THE TIN MELT TANK ATMOSPHERE ON MICROHARDNESS OF FLOAT GLASS SURFACE

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The effect of the content of water steam and oxygen in the tin melt tank atmosphere on the microhardness of float glass surface layers was investigated at various Russian and Ukrainian enterprises. It is demonstrated that an increase in the water steam content does not significantly decrease the surface microhardness. At the same time, an increase in the molecular oxygen concentration produces a decrease in the surface resistance to abrasive particles.

The aspects of the effect of water steam which comprises part of the protective atmosphere of the tin melt tank on the structure and properties of thermally polished glass surface are discussed in numerous publications (USA patent 3498803) [1, 2]. The authors in their analysis usually assume that water steam acts as a surfactant which chemically reacts with the glass surface and plasticizes the surface layer, thus decreasing its microhardness. The sources of water steam are usually identified as technological causes related to the production of the protective atmosphere components by natural gas combustion and to the chemical interaction of the residual oxygen in the protective atmosphere with hydrogen. However, this cannot account for all data accumulated in the operation of float glass production lines.

The purpose of the present work is the integrated study of the effect of the content of molecular oxygen and water steam in the protective atmosphere composition on microhardness of the surface layers of thermally polished glass. The investigation summarizes the long-term practical experience of measuring float glass surface layers performed at different industrial and experimental production lines in Russia and Ukraine (Saratovsteklo, Saratov Institute of Glass, Salavatsteklo, Borskii Glass Works, Avtosteklo, and Lisichanskii Glass Works).

The microhardness was determined on a PMT-3 microhardness meter by measuring a diamond indenter imprint under various loads applied to glass samples 5 mm thick which were obtained under similar technological conditions (the volume content of hydrogen in the tin melt tank protective atmosphere was 4 – 5%, the speed of glass band output was 380 – 460 m/h, the glass melt temperature in the working channel of the glass-melting furnace was 1010 – 1020°C) but with a different quality of the protective medium (varying contents of molecular oxygen and water steam). The water steam content in these cases was determined by the dew point, and the oxygen concentration was found using a LKhM-8 MD gas chromatograph.

The summarized data of the measurement results are shown in Fig. 1.

It should be noted that the nature of the dependences of the surface layer microhardness on the content of molecular oxygen and water steam in the protective atmosphere is fundamentally different.

When a low load is applied to the indenter and the surface microhardness to a great extent is determined by the structure of the outer surface layer [3], the curve of the dependence of the microhardness of the float glass bottom surface on the water steam content in the protective atmosphere exhibits a clearly defined minimum. Moreover, a low or high load applied to the indenter results in significantly different curves of microhardness relationship to the oxygen and water steam contents, which is another evidence of the differences in the structures of the first and the second surface layers in float glass. As was shown in [3], the second near-surface layer, whose structure is more bonded than that of the first surface layer, offers more resistance to the indenter pressure, which results in the higher microhardness. However, these differences are leveled as the molecular oxygen content in the protective atmosphere increases or the water steam concentration decreases. The correlation between these data suggests that the main amount of water steam in the protective atmosphere of the tin melt tank is formed due to chemical processes with participation of oxygen.

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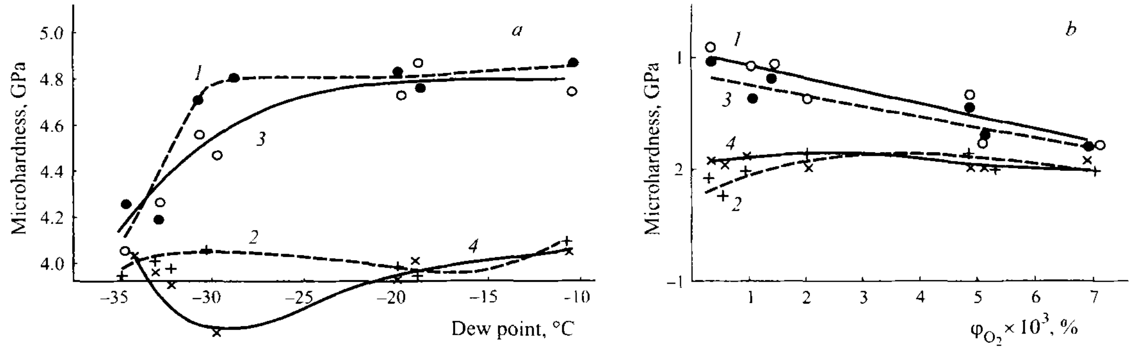

Fig. 1. Dependence of microhardness of upper (*1*, *2*) and bottom (*3*, *4*) surfaces of float glass on the content of water steam (*a*) and the volume content of oxygen (*b*) in the protective atmosphere of the tin melt tank under a load of 100 g (*1*, *3*) and 50 g (*2*, *4*) applied to the indenter.

Let us consider the reasons for the observed regularities. The presence of the minimum on the curve of microhardness versus the water steam content can be explained by the fact that as the water steam concentration increases up to a level corresponding to the dew point above 20°C, the water steam can act as crystallization process catalyst in the thin surface layers of silicate systems [4]. As a consequence of that, a more rigid crystalloid structure is formed in the thin surface layer which is responsible for the glass surface microhardness under low loads applied to the indenter.

On the other hand, when the water steam content in the protective atmosphere is very low, the structure-forming mechanism of the first upper surface layer of float glass is modified. As was shown earlier [5], there are two fundamentally different mechanisms of the chemical processes which accompany surface formation in multicomponent silicate glass and ensure a decrease in the excessive surface energy by means of interaction with the surface-active components of the gas atmosphere (primarily, with water steam) and through the restructuring of the oxygen-elemental skeleton of the glass surface layers with emergence of a more bonded and more energy-efficient structure.

The second mechanism prevails in surface formation when the concentration of surfactants in the phase contacting the forming surface is insufficiently high, and also occurs in deeper layers which are located sufficiently close to the surface to be affected by the excessive surface energy of the newly formed surface, but at the same time sufficiently deep to allow the gas atmosphere surfactant components absorbed by this surface to diffuse into these layers. As a consequence, the deficit of the water steam content in the protective atmosphere decreases the thickness of the first surface layer whose looser structure determines the lower microhardness of such surface under low loads on the indenter, and the microhardness level virtually ceases to depend on the force of the indenter pressure.

It has to be noted that the concentration of molecular oxygen in the protective atmosphere has a greater effect on the microhardness of the upper and the bottom float-glass surface than the water steam concentration. In the case of the bottom surface, this can be explained by the effect of oxygen on the extent of tin oxidation in the melt tank. As for the upper surface, the only explanation of the greater effect of the oxygen concentration on microhardness as compared to the water steam effect can be the assumption of its chemical reaction with the cooled glass surface, as a consequence of which the oxygen acts as a surfactant component of the atmosphere. The processes with participation of various structural defects of glass surface, such as oxygen vacancies, can be suggested for consideration in the capacity of such chemical processes.

Thus, the highest risk of losses in glass surface mechanical strength under abrasive actions is represented by large particles (deep scratches, indentations), i.e., when the effect on the glass surface is accompanied by the disturbance of the structure to a substantial depth. Therefore, to produce glass with increased mechanical strength, the content of molecular oxygen in the melt tank protective atmosphere should be decreased. On the other hand, an increase in the water steam content does not decrease the microhardness of either the upper or lower float glass surface, and increases its resistance to abrasive particles.

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